Preparing for Oxford Physics 2026 – Resource Pack 1

Department of Physics
UNIVERSITY OF OXFORD

Introduction

Welcome to the 'Preparing for Oxford Physics" course at the University of Oxford. We hope you find the course useful and informative, and have fun solving some physics problems!

This course is aimed at improving your problem-solving skills, a key requirement for the ESAT, for Oxford physics interviews and for the science degree courses you will be starting before you know it.

This course is made up of live webinars, problem sets, Isaac Science question decks and videos. Through all of this, we aim to provide you with a toolkit of techniques for tackling physics problems and to give you a structure to help you with your preparation for university physics.

We do not make any guarantee that by attending this course you will do well in the ESAT and beyond, but we do hope to help you become more curious physicists with a greater appreciation of the skills needed for problem solving.

The material in this booklet has been written by Dr Justin Palfreyman and Mrs Kathryn O'Brien Skerry, with material adapted from a previous version of the course written by Dr Justin Palfreyman, Mr Alby Reid and Ms Rachel Martin – many thanks to them for the hard work involved in producing this material. We all hope you enjoy the course.

- Kathryn O'Brien Skerry, Physics Access Officer, University of Oxford

Contents

Introduction 2
Guide to Thinking like a Physicist 4
  Writing up Clear Solutions 4
    Model Solutions: Example 6
  Thinking 8
    Dimensional analysis 8
    Conservation laws 11
    Alternative methods: 11
    Modelling 13
    Simplifications 15
    Frames of reference 16
    What If? 16
    Proportionalities 18
  Spoilers/ Clues 18
Where to practice problem solving. 19
Webinar 1: Think like a Physicist 20
  Part I: Probability and Assumptions. 20
  Part II: Building a problem solving toolbelt 23
Hints for Webinar 1: Think Like a Physicist 26
Problem Set 1: Think Like a Physicist 28
Hints for Problem Set 1: Think like a physicist 31
Webinar 2: Tackling Physics Problems 32
    Building The Great Pyramid of Giza – Part I 35
Hints for Webinar 2: Tackling Physics Problems 37
  Building The Great Pyramid of Giza – Part II 41
Hints for Problem Set 2: Tackling Physics problems 44

Guide to Thinking like a Physicist

Writing up Clear Solutions

Communication is an important skill in many aspects of our lives. Communication, though, is not just about speaking. When you write essays or work out science problems, the conclusions are important but do not tell the whole story - the journey is where the true excitement lies.

In science, clear working is the way that we communicate that whole story. Developing clear working takes time but is easy to get better at just by practicing.

Your written work should be easy to follow for anyone looking at it (e.g. an examiner! / teacher / friend or you when you come to revise in a few months)

Get into the habit early. You will find it helps you to **think and plan logically** and makes life easier for you and the person reading your work. Even if a question is simple enough that it can be done in your head, practice the following steps so that they become muscle memory when it comes to tackling harder questions. Train yourself on the challenge questions on Isaac Science.

A good solution will often have a healthy mix of **diagrams**, **words**, **equations**, **symbols** and **numbers**:

> **Diagrams** are often a good place to start a question. It's a clear way to summarise all the key data and helps you to picture what is actually going on.
>
> Check your diagram:
>
> - is a good size – you should have space to add in labels and anything that comes up while you are working on a problem
> - is meaningful but not unnecessarily cluttered - this is what a horse looks like in physics: □
> - is complete and consistent in notation - if you're going to calculate a length or an angle etc., it should be labelled on the diagram.
>
> **Words** are a crucial part of telling any story. They help set up a problem and explain why you use a particular equation. Make sure that you state the necessary physical principle before you first use it. For example, "by conservation of energy: $\Delta KE = \Delta PE$".
>
> There must be a logical flow to the work. If one line implies another, use **symbols** to connect them:

symbol	meaning	Usage
" ... "	Quotation marks	Introducing the physics principles or equations at the start
⇒	Implies that	Between lines of connected working, to show one statement leads to the next
∵	Since	When adding extra reasoning that is not trivial
≈	Approximately equal to	When rounding a numerical answer to an appropriate number of sig figs
∴	Therefore	To express the final line leading to the solution
Q.E.D	As required (to be demonstrated)	At the end of a "show that" style question to signify completion

Label equations you are going to use again with stars or numbers, and refer to them later. For example, "substituting for 't' from (*) into (**) gives:".

Numbers: We are usually interested in a numerical result at the end of a problem and this is when to substitute in numbers – at the end! Simple numbers and fractions are exceptions to this rule. Most physics is done without a calculator. There are several good reasons for doing this, including...

Intermediate evaluation and rounding can lead to errors

- It removes the "worry" about how many significant figures to write out
- It's quicker: try writing 'g' out ten times, then write out "$9.81 m.s^{-2}$" ten times.
- Most importantly, it allows you to change a variable (e.g. an angle) and not repeat the whole calculation.

When evaluating answers or quoting numerical values, remember to think about **significant figures** and don't forget **units**.

Model Solutions: Example

It takes most people a lot of practice to get into the habit of producing high-quality model solutions[1]. Look over some of your best work and judge it against these three questions…

1. Is it clear what the question is from the solution? (no need to copy out the question).
2. Would someone unfamiliar with the topic be able to follow all the steps clearly?
3. Would re-reading this solution be useful for you revising the topic 6 months later?

The model solution on the next page (from 2014) ticks all three of these boxes. If you are diligently following these 6 steps you are likely to be on track. Can you identify where each of these was used?

1. Draw a well-annotated diagram when useful
2. State/ ”quote” the key physics principles/equations needed
3. Rearrange the equations, staying in algebra as long as possible
4. Show all values substituted for, including constants like g
5. Give your answer to an appropriate number of s.f. first time with units
6. Check the working is structured logically, using connectives… $\therefore$ $\approx$ $\because$ $\Rightarrow$

[1] Further similar examples can be found in this book: https://isaacscience.org/books/solve_physics_problems

4.3 Resistance - Summary questions 02-11-2014

1. a) Using Ohm's law "$V = IR$", we can find the missing values in the table:

(i) $R = \frac{V}{I} = \frac{12.0V}{2.0A} = 6.0\Omega$

(ii) $V = IR = 0.45A \times 22\Omega = 9.9V$

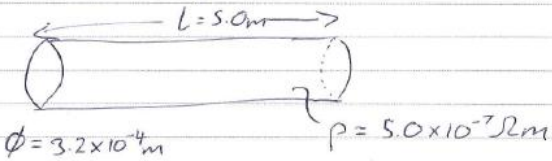
(iii) $I = \frac{V}{R} = \frac{5.0V}{4\times10^4\Omega} = 1.25\times10^{-4}A \approx 0.13mA$

(iv) $R = \frac{V}{I} = \frac{0.80V}{5.0\times10^{-3}A} = 160\Omega = 0.16k\Omega$

(v) $I = \frac{V}{R} = \frac{5\times10^4V}{2\times10^7\Omega} = 2.5\times10^{-3}A = 2.5mA$

b) From figure 2, gradient $= \frac{V}{I} = R = \frac{15.0-0}{2.0-0} = 7.5\Omega$

2.



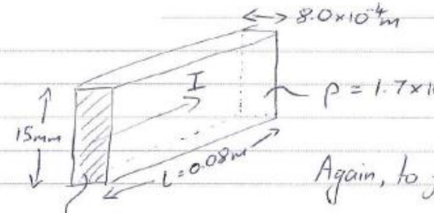
To find the resistance we can use: $R = \frac{\rho l}{A}$

where $A = \pi r^2 = \frac{\pi d^2}{4}$,

so $R = \frac{5.0\times10^{-7}\Omega m \times 5.0m}{\pi/4 \times (3.2\times10^{-4})^2 m^2} = \frac{1.0\times10^{-5}\Omega}{\pi(3.2\times10^{-4})^2}$

$\approx 31\Omega$

3.

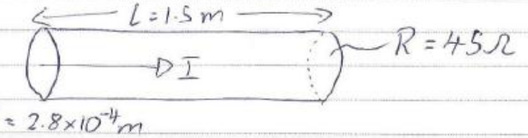


Again, to find R, we use: $R = \frac{\rho l}{A}$

Now $A = 1.5\times10^{-2}m \times 8.0\times10^{-4}m$

So $R = \frac{1.7\times10^{-8}\Omega.m \times 8\times10^{-2}m}{1.5\times10^{-2}m \times 8.0\times10^{-4}m} = \frac{1.7\times10^{-10}\Omega}{1.5\times10^{-6}} \approx 0.11m\Omega$

4.



a) To calculate the resistivity, we rearrange: $R = \frac{\rho l}{A}$ *

$\Rightarrow \rho = \frac{RA}{l}$

Substituting from above: $\rho = \frac{45\Omega \times \pi(2.8\times10^{-4}m)^2}{4 \times 1.5m}$

$\approx 1.8(5)\times10^{-6}\Omega m$

b) To find the length that has resistance of 1.0Ω, we could rearrange and use $l = \frac{RA}{\rho}$ and substitute for all these terms.

However, since $R \propto l$ (seen from *), to have $\frac{1}{45}$th of the resistance it must have $\frac{1}{45}$th the length, so $l = \frac{1.50m}{45} \approx 3.3$

Thinking

Physics is not simply “doing” maths. To be good at physics it helps to be mathematically fluent, but the true skill of a physicist is to turn a real-life situation into an appropriate model, and then searching for the **simplest path** to solving it.

Physics is mostly not a test of memory. There are however a few facts and formulae that are so fundamental they must be committed to memory. Nevertheless, it is much better to be confident in deriving others from **first principles**.

There are a number of tricks that can help with this.

Dimensional analysis

This is an incredibly useful skill and, the great thing is, it only requires you to remember the quantities involved and their units (dimensions). Since you know the associated units, with practice, this will actually be simpler. It can also be used to check ‘new’ relationships. Let’s look at some examples:

1. You’re asked to find the specific heat capacity of something, and am told that it has units of $J.kg^{-1}.K^{-1}$. If you are provided with energy, mass and change in temperature, it is easy to form the correct equation:

$J.kg^{-1}.K^{-1}$ = [J] / ([kg]x[K])

⇒ specific heat capacity = Energy / (mass x change in temp.)

Caution: dimensional analysis cannot tell you anything about dimensionless constants, these must be remembered!

2. Say you’re unsure of which of these is correct:

“$s = at + ½\,ut^2$” or “$s = ut + ½\,at^2$”.

Since we know the dimensions of the quantities: distance [m]; acceleration [$m.s^{-2}$]; velocity [$m.s^{-1}$]; time [s], we can quickly check which is dimensionally correct:

[m] = [$m.s^{-2}$]x[s] + [$m.s^{-1}$]x[s]^2 = [$m.s^{-1}$] + [m.s]

or [m] = [$m.s^{-1}$]x[s] + [$m.s^{-2}$]x[s]^2 = [m] + [m]

Now try applying this idea to this real-life multiple-choice exam question. It doesn't matter if you have covered circular motion yet, in fact, we've cropped the stem of the question and just given you the 4 (im)possible answers.

Which one of the following expressions is equal to M?

A $\dfrac{mv^2}{2r}$

B mv^2rg

C $\dfrac{mv^2}{rg}$

D $\dfrac{mv^2g}{r}$

There are plenty of multiple-choice questions (even on the ESAT) where you can eliminate some or even all of the wrong answers just by using this skill.

3. If you are trying to formulate the equation for centripetal force, we can do this with just a little imagination. Imagine you are spinning a conker on a piece of string above your head in a horizontal circle.[2] When you do this you will experience a force as your hand needs to pull on the string. You reason that there are only three things you could reasonably change about this scenario that would affect the force, F, namely.

- The speed of rotation, v
- The radius of the circle, r
- The mass (i.e. size) of the conker, m

If true, we can go about writing an expression of the form: $F \propto m^{\alpha} v^{\beta} r^{\gamma}$

How can we determine the value of the exponents in this expression? That can be done using dimensional analysis in only a couple of steps!

Step 1: Replace the quantities with their units: $[\mathrm{N}] \propto [\mathrm{kg}]^{\alpha} [\mathrm{m\ s^{-1}}]^{\beta} [\mathrm{m}]^{\gamma}$

Step 2: Make sure everything is in SI base units: $[\mathrm{kg\ m}\ s^{-2}] \propto [\mathrm{kg}]^{\alpha} [\mathrm{m\ s^{-1}}]^{\beta} [\mathrm{m}]^{\gamma}$

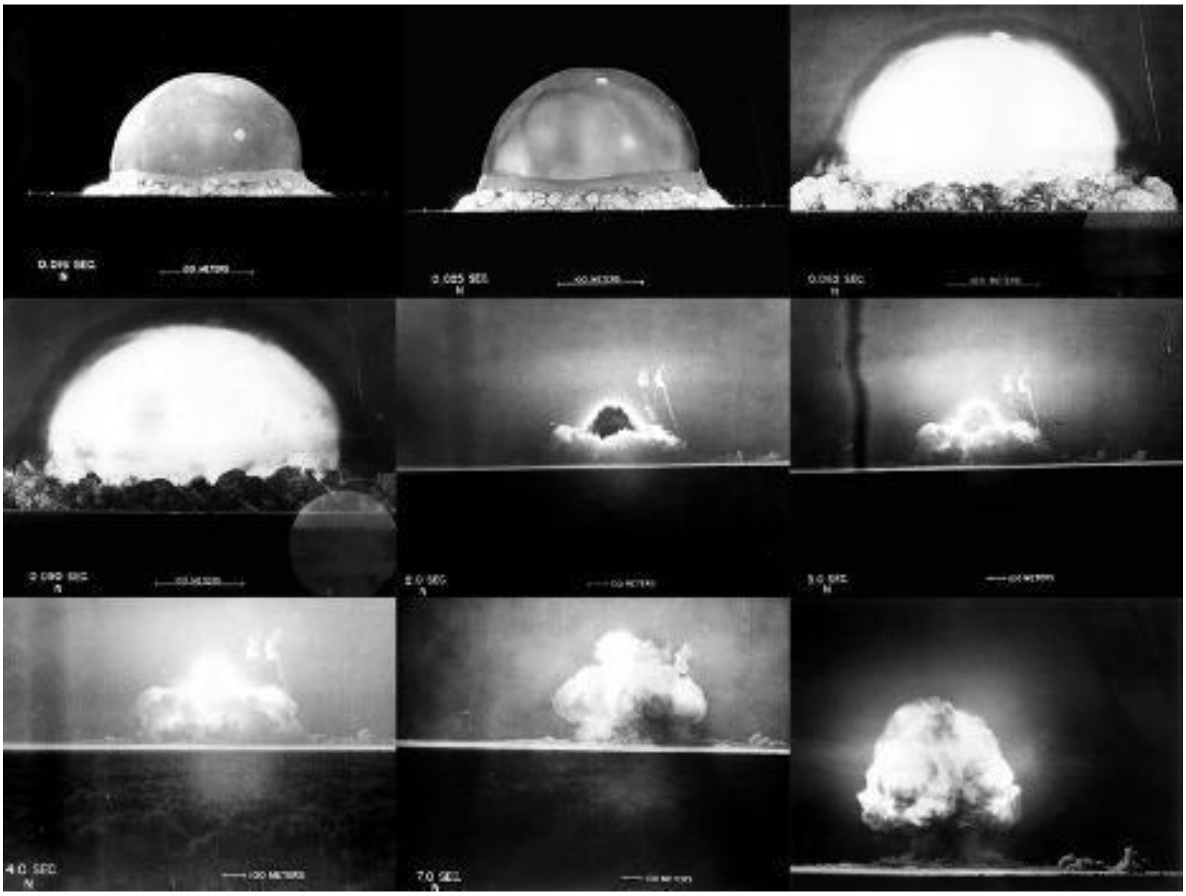
Step 3: Separate the terms – this is actually 3 equations in one, and there are 3 unknowns.

You will now have shown that $F \propto \frac{mv^2}{r}$, but there could be a dimensionless constant of proportionality – probably to do with pi, since it's circular motion. If you wanted to

[2] This is impossible to do on Earth, since you'd need a component of the tension in the string to cancel out the weight of the conker. If you wish, you can imagine you're doing this in deep-space, but then which way is "horizontal"?

discover that, you'd need to either test it experimentally (empirical) or develop a theoretical derivation for the centripetal force, which is a little trickier.

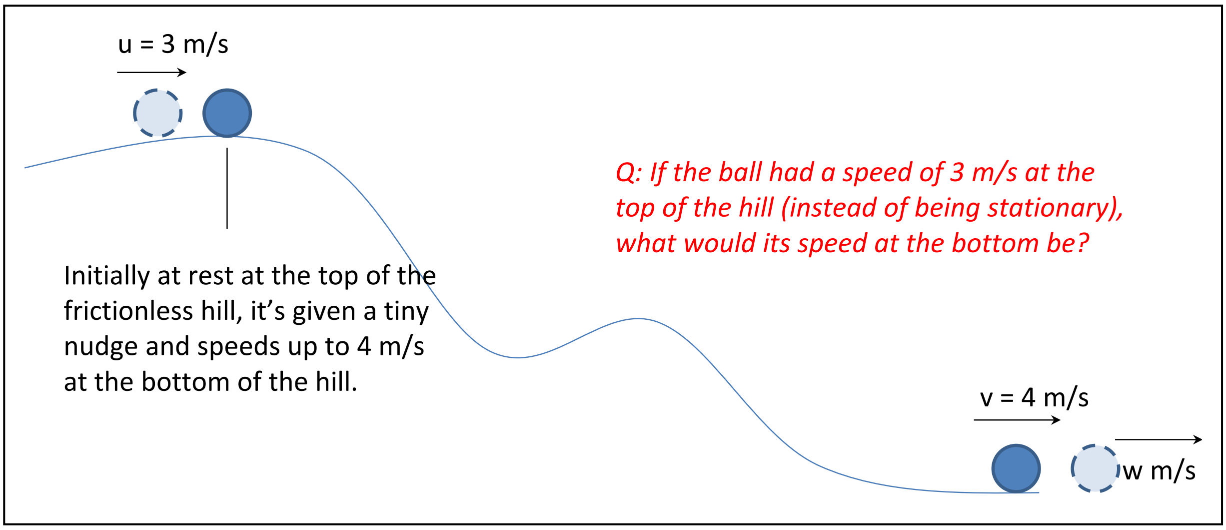
4. Let's say you wanted to estimate the energy of an atomic bomb, a military secret, by looking at a series of still images, thankfully time-stamped with a scale-bar!



It is often told that British Physicist Sir G.I. Taylor did exactly this in 1947 by reasoning that the blast radius would be some function of the time, energy and density of air. It's not quite true, **but** it does make for an excellent example of the power of dimensional analysis as explained by Dr Trefor Bazett at https://www.youtube.com/watch?v=yJ4wCyHSV3s –

Conservation laws

Physical 'things' don't simply disappear or appear from nowhere[3]. This familiar principle can be applied to many problems, particularly when we know what we have at the start and want to find out what we have at the end of a process, but there may be something quite complicated happening in the middle. Consider the following problem:



It is possible to solve a problem like this using a **forces and SUVAT approach.** You can work out how to do that for yourself if you want to[4]. However, the much easier approach here is to use **conservation of energy** …

$$\frac{1}{2}mv^2 = mg\Delta h \Rightarrow v = \sqrt{2g\Delta h}$$

Other examples:

- Electricity: Kirchhoff's Laws tell you how charge (i.e. current) and energy (i.e. potential difference) are conserved in electric circuits.
- Nuclear Physics: radioactive decay is simply a matter of balancing the number of nucleons (protons + neutrons) and charges on each side of an equation. Thanks to Einstein's $E = mc^2$ it's actually mass-energy that you'll need to conserve also.
- Mechanics: (angular) momentum is always conserved in a closed system (this is why the solar system is spinning and the moon is moving away from the Earth).
- Particle physics: the possibilities for particle interactions/decays seem endless, now you'll need to keep track of lepton and baryon numbers and strangeness – some of the time.

Alternative methods:

There's often more than one way to solve a particular problem and the obvious/intuitive way is often the long way. Keep an open mind and be on the lookout for alternate ways

[3] This is not exactly true, to learn more about this and Noether's Theorem, you may want to watch this: www.youtube.com/watch?v=04ERSb06dOg

[4] Clue – does the shape of the slope actually matter in this example? Simplify!

that you can approach the problem that will save you some work. If it's a mechanics question, as we saw on the last page, should you be thinking about forces and/or energy?

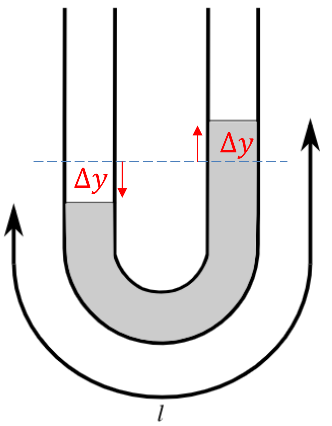
If/when you've studied simple harmonic motion (SHM), you should test yourself with this question: https://isaacscience.org/questions/mercury_u_tube

Your instinct might be to use a forces approach to solve this. It's likely how you would have derived the equations for a pendulum and a mass on a spring. When it gets tricky, it might actually be easier to use energy conservation:

Part A Period of oscillation

Mercury of density $\rho = 13.6\,\mathrm{g\,cm^{-3}}$ is contained in a U-tube with parallel, vertical arms. Initially the height of the mercury in the two arms is different.

Since total energy is conserved, $\frac{dE}{dt} = 0 = \frac{1}{2}\rho l S \frac{2dv}{dt} v + \rho S g \frac{2dy}{dt} y$



By comparison with SHM, we recognize that:

$\omega = \sqrt{\frac{2g}{l}}$

Simplifying gives: $la = -2gy$

Figure 1

Neglecting damping, what is the period of oscillation of the mercury if the total length of the tube occupied by mercury is $l = 40.0\,\mathrm{cm}$ and the level of the mercury remains in the vertical part of the arms at all times?

Energy approach

Consider a displacement from equilibrium Δy

The change in GPE is $mg\Delta h = (\rho \Delta y S) g \Delta y$

As the fluid travels at a speed $v = \frac{dy}{dt}$ it has KE: $\frac{1}{2}Mv^2 = \frac{1}{2}\rho l S v^2$

Total energy in the system is therefore: $E = \frac{1}{2}\rho l S v^2 + \rho S g y^2$

The "trick" is to differentiate your equation for total energy with respect to time – since it is conserved, it doesn't change with time, so this must equal zero – you can then cancel out lots of common terms!

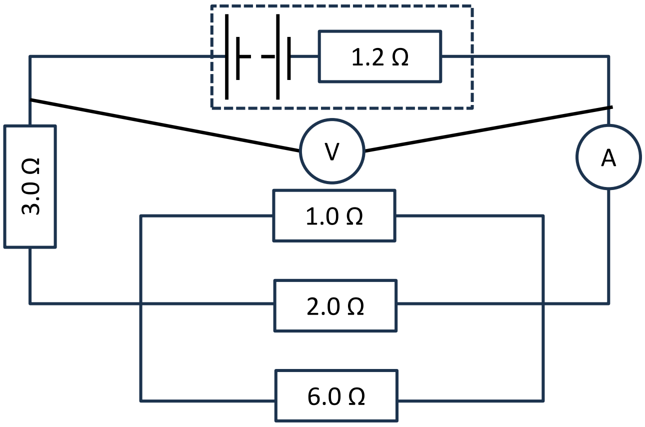
If you have electrical circuits which also display oscillatory behaviour, e.g. (R)LC circuits (inductors and capacitors), you can use this "trick" to find the differential equations associated with these!

For simpler electricity problems, which a student in Y12 or equivalent would be expected to solve, you may want to decide whether you should be using **resistor combinations and Ohm's law** (twice) or whether a simpler application of **Kirchhoff's Law(s) or**

potential dividers is the best route. Usually, but not always, one of these methods will be significantly easier and/or quicker.

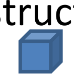
Consider this circuit, with a battery with an EMF of 8V. Can you determine the reading on the voltmeter with and without using Ohm's law?

In an exam, you may have been guided in the route to use. For instance, in the previous part, were you just asked to state Kirchhoff's 2nd law?

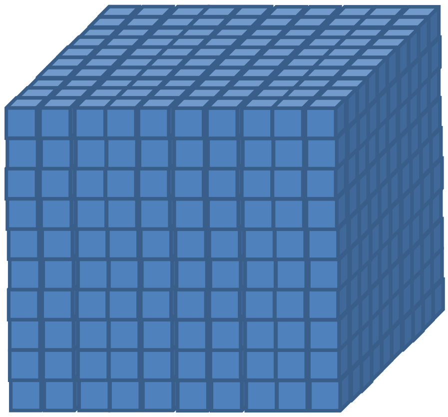


Could you change the question into the opposite question? You'll likely be familiar with this approach when working out probabilities – rather than add up all the possible combinations, it might be better to find out the probability of something not happening, then just subtract that from 1 to find what you really wanted to know.

Consider the **Mega Cube** problem below – another classic.

A 10 by 10 by 10 cube is constructed from a thousand unit cubes. 

How many of the unit cubes have at least one face on the surface of the larger cube?



You might start with 600 and then think about the sides and the corners where you've double and triple counted and take them off. This is a long process and very easy to make a mistake – go on, give it a go.

Now try to do it by asking the opposite question: how many cubes are NOT on the outside surface?

Modelling

Physicists use models to describe the natural world, and when we do this, we are massively over-simplifying things and making seemingly ridiculous assumptions…

To derive Young's double slit or the diffraction grating formula, we assume that the rays from the two slits which **meet** at the screen to form a bright spot are parallel. The property of lines which makes them parallel is that they **never meet**!

To derive the equations for the time period of a pendulum, which is independent of the angular displacement, we must use small angles ($< 10°$), such that $\sin\theta \approx \theta$ (in radians).

We make these kinds of simplifying assumptions all the time… ignoring air resistance; resistance-less wires and ideal batteries or diodes; smooth slopes and pulleys; light-inextensible strings; the ideal gas law – an empirical law (made from observations only) can be united with molecular kinetic theory. The latter assumes the gas atoms do not interact with each other, but the Maxwell-Boltzmann distribution relies on the fact that they do. When the most energetic gas particles escape the Earth's atmosphere, the distribution soon recovers.

Most of what you think you know about the Universe isn't strictly true – it's a simplification of more complex ideas. Does that bother you?

If it does, then that's great. You'll have to continue studying physics to get closer to the truth – you're not yet ready for the mathematics you'll need to understand it. However, the more you learn, the more you'll realise you don't know!

"True wisdom is knowing you know nothing at all" – Socrates

If it doesn't bother you, then that's great too. Using the more advanced models might change your answer at the third or fourth significant figure, but considering the limitations of your measurements, you probably weren't justified in giving that many significant figures anyway. The pay-off in being able to do the calculations quickly is what makes physicists great problem solvers.

"Everything should be made as simple as possible, but not one bit simpler" – Einstein

Simplifications

Now you've realised the necessity of using models, can we find ways to make them even simpler?

Consider the problem below, and think about the assumptions[5] we must make to solve it.

Each summer, when the grass at Queniborough reaches a certain height, Phil goes to the uniform cow shop and rents some uniform cows to graze on it, until it reaches a particular level. He then hires out a marque and hosts a party to celebrate this triumph over nature.

From the previous 2 years Phil knows that it took...

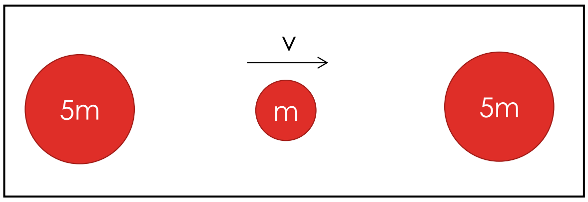
- 6 cows, 4 days to do the job
- 3 cows, 9 days to do the job

Word of mouth about uniform cow rental has meant demand now outweighs supply, and this year he can only rent 1 uniform cow.

Scared that he won't be able to get a marque at short notice, he decides he needs to book it now. When will the field be ready this year?

If the actual shape of something is not important, then draw it as a point mass and just consider the forces acting on that – its centre of mass. These are free-body diagrams, completely unrealistic in the real world, but all you need to apply the laws of nature. Astronauts onboard the ISS might admire the beauty of Earth from space, but their motion is dictated just the same as if it was a point mass.

Look out for **symmetries**, even when not immediately obvious. Take this 3 ball elastic collision problem, where the task is to determine the total number of collisions and the final velocities of all 3 masses.



Once you've found the velocities from the first collision and the ball of mass m is now travelling to the left with a velocity u, the result of the second collision will be identical to that of the first, albeit in terms of u rather than v.

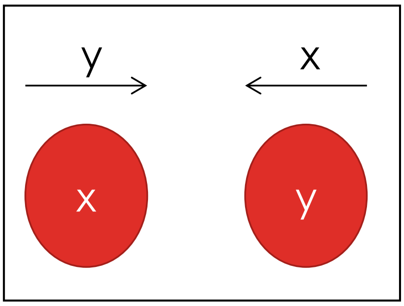
Have you considered that a negative charge moving to the right looks exactly the same as a positive charge moving to the left? Even with electrical and magnetic field lines it can be helpful to draw (imaginary) reflections, of the opposite charge or pole.

[5] You can picture a uniform cow density, spread out across the whole field, grazing everywhere at a constant rate.

Frames of reference

Should you learn special relativity (e.g. AQA Turning Points), then you will become very familiar with switching between (inertial) frames-of-reference. Even if you don't cover this at school, learning this skill will help you to simplify and solve many other types of problems.

A particularly useful frame-of-reference for analysing 1 or 2-dimensional elastic collision problems is the **zero-momentum frame** – a frame in which the centre of mass of the system appears stationary.



This transformation will make every collision as trivial as this one. In order to conserve linear momentum and kinetic energy, can you *see* from inspection what the velocities must be after the collision? Although this looks like a special case, we can show that any collision can be transferred into a frame where the total momentum is zero, so the collision simply means flipping the direction of the velocities.

For example, try solving the following question[6]:

A particle of mass m travelling with speed $V = 1.0\ \mathrm{ms}^{-1}$ along the $+x$ direction collides elastically with a stationary particle of mass $2m$. The particle of mass m is deflected through an angle of $30°$.

What is the speed of the heavier particle in the laboratory frame following the collision?

What If?

Being flexible with the perspective you view a situation from can be extended to asking yourself "*what if the scenario were different?*"

You need to be careful with this approach though, as it can lead to paradoxical arguments, for example, my Geography teacher warned the class there would be a *"surprise test this half-term".* I used the following line of reasoning to "prove" this couldn't happen…

- Had we got to the last lesson of the term and the test hadn't happened, it must be that lesson, which wouldn't be a surprise… so it couldn't be in the last lesson.
- Had we got to the penultimate lesson of the term and the test hadn't happened. Since it couldn't be saved for the last lesson, it must be that lesson, which wouldn't be a surprise… so it couldn't be in the penultimate lesson either.
- I applied this logic backwards through every lesson to prove it simply wasn't possible, yet 2 weeks later when the test occurred – I was surprised (and not well-prepared).

[6] Check your answer here: https://isaacscience.org/questions/elastic_collision_ZMF_num (part B)

Can you apply that kind of reasoning to the following two questions?

1. Greedy Pirates

Despite their reputation, pirates may surprise you, especially when it comes to dividing their plunder. They live by the following set of rules.

- There is a hierarchy: Captain, Vice-Captain, Look-out, Chef, Potato-peeler
- They are democratic: A decision needs 50% or more of the vote to pass
- They are ruthlessly logical and greedy.

Following a raid, 100 gold pieces are on the table. The captain will suggest how the loot should be split up. All 5 of the crew will then vote on this.

Should the captain lose the vote there will be a mutiny and he will be forced to walk the plank. The vice-captain will then suggest how the gold is split and there will be another vote and so on….

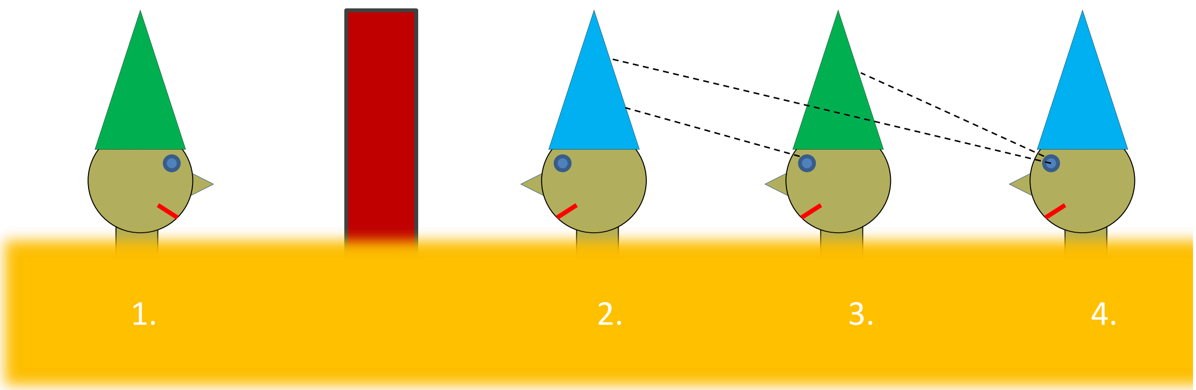
How much gold can the Captain keep for himself and still win the vote[7]?

2. Buried in the Sand

Jos, Julia, Kunal and Iva get lost in the dessert while foraging. They come across a particularly nice wall and stop to admire it for a while.

Sadly, the local ruler spots them and accuses them of trespassing. Following desert law, the ruler commands the army to bury Jos, Julia, Kunal and Iva up to their necks in the sand – ironically positioned so they can continue to admire the wall.

The ruler sets Jos, Julia, Kunal and Iva a challenge to win their freedom.



The army first blind fold Jos, Julia, Kunal and Iva and then place coloured hats on their heads, before removing the blind folds. Jos, Julia, Kunal and Iva are aware there are 2 blue and 2 green hats and of their own relative positions.

[7] Solve a similar problem to this and over 200 more here: https://i-want-to-study-engineering.org/q/pirate_game

"If anyone can name the colour of their own hat, you will all be free to go. If anyone gets it wrong or says anything else, I'll leave you buried in the sand." How can they escape?

Proportionalities

It's quite common to be asked something of the type:

"What happens to w if x was doubled, y was quartered and z was increased by a factor of 9?"

This can almost always be done algebraically, without the need to actually calculate any new values. As an example, let's imagine we've just been calculating Rutherford's over-estimate for the radius of the nucleus by firing alpha particles at gold foil:

$$r = \frac{Ze^2}{\pi\varepsilon_0 mv^2}$$

And we were asked how r would change if back-scattering was observed from aluminium foil rather than gold. Rather than actually calculate r from scratch again, the only thing we're changing[8] in this equation is Z which was the atomic number of gold.

We can simply state that since $r \propto Z$ and that Z has decreased by a factor of 13/79, so too must r. All those other constant terms can be neglected.

It has often been said that "mathematics is the language of physics". In order to do well in physics, one must therefore become a good *translator*.

Spoilers/ Clues

Mega-cube: 488 (=$10^3 - 8^3$)

Rent-a-cow: 54 days, did you spot why it was non-linear? Then make sure you know what a cow-day and a cow-day-per-day represent physically.

Consider the ZMF for the first collision – you can ignore the $5m$ ball on the left. The ZMF will be travelling to the right at speed $v/6$. In this frame, the relative velocities of the balls are $\frac{5v}{6}$ and $-\frac{v}{6}$. Switching directions after the collision and transferring back into the lab frame, the $5m$ ball will now have velocity $v/3$ ...

Greedy pirates: The pirate captain can keep 98 gold coins. How would it be split if it got down to just the Chef and Potato-peeler?

Buried in the sand: Number 3 can be almost 100% confident, after a short wait.

[8]Note: we assumed there was no recoil of the gold nucleus, this would be much less of a fair assumption for aluminium. We'd now be getting so close that the strong nuclear force or magnetic interactions couldn't/shouldn't be ignored, and we're much more likely to penetrate the nucleus rather than be back-scattered. You're not expected to know that, don't worry!

Where to practice problem solving.

A habit of doing a little problem solving each day is a fantastic way to improve your skills and a great place to do this is at www.IsaacScience.org which is entirely free.

You can also access Paul Hewitt's whole collection of Next-time questions, which are freely available here: https://www.arborsci.com/pages/next-time-questions

There are over 200 Maths and Physics puzzles you can try at https://i-want-to-study-engineering.org with video solutions.

You can also take a look at www.brilliant.org,

If you like conceptual physics puzzles, I'd recommend reading these books.

- Thinking Physics by Lewis Carroll Epstein
- Professor Povey's Perplexing Problems by Thomas Povey
- What If? (1 and 2) by Randall Munroe

Webinar 1: Think like a Physicist

10th June 2026

Part I: Probability and Assumptions.

"The first principle is that you must not fool yourself and you are the easiest person to fool" – Richard P. Feynman

When it comes to probability questions, it turns out that most people's **intuition** will lead them to the **wrong** answer, and it takes considerable training to bypass your brain's auto-pilot, particularly when dealing with conditional probability.

You should be well-practiced with drawing tree and Venn diagrams to tackle straight-forwards probability questions[9].

Note: You should **not** need a calculator for ANY of these problems.

1. **Die Rolls**

   Which is the most likely sequence of die rolls?

   (a) 1 3 6 2 6 3 1 6

   (b) 1 3 6 5 2 6 3 1 4

   (c) 1 6 1 6 1 6 1

2. **π versus e**

   What is the probability of finding the consecutive sequence of digits ...123456789.... in:

   a) $\pi \approx 3.14159265358979323846264338327950288419716939937510582097494\ldots$

   b) $e \approx 2.71828182845904523536028747135266249775724709369995957496696\ldots$

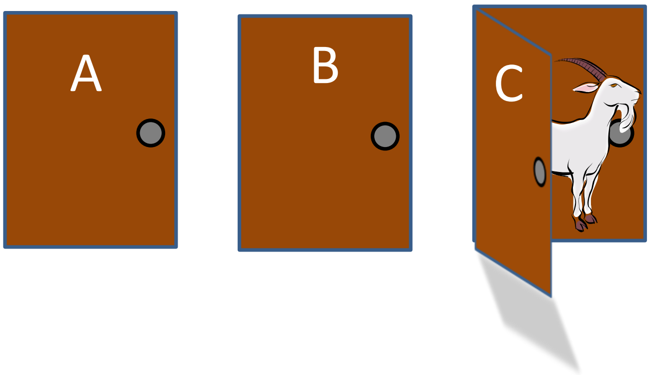
3. **Monty Hall**

   This problem split the academic community down the middle[10].

   Here's the set-up: In the prize round of a gameshow, you are presented with the choice of selecting one of three identical doors. Behind one of the doors is a car, behind the other two are goats – you really don't want a goat.

[9] If you want to practice some probability, try out these 2 boards on Isaac Science: https://isaacscience.org/question_decks#maths_book_gcse_ch9_52_higher , https://isaacscience.org/question_decks#maths_book_gcse_ch9_53_higher

[10] Its Wikipedia page has 69 references! https://en.wikipedia.org/wiki/Monty_Hall_problem



You selected door B at random – you had a 1 in 3 chance of being correct.

The gameshow host (who knows the location of the car), says "it's a good job you didn't pick door C" as he opens it to reveal a goat. All of a sudden your odds have improved to 1 in 2 – fantastic!

You know what's coming next, it happens every week – your final decision…

Will you stick with your original selection, or are you better off by switching to A? What does your gut tell you?

4. Three daughters?

Imagine I have 3 children, and I pull out a photo from my wallet to show you a picture of one of my children at random, who just so happens to be a girl.

a) Given this, and only this information, what is the probability that I have 3 daughters?

b) Would the probability change if I were to tell you that she was my eldest, youngest or favourite child?

c) What if she was holding a trophy in the picture, and we could infer that of my 3 children, she was the most sporty?

5. Black and White

Three cards are shuffled and laid out under a cloth. You know that one card is white on both sides, one is black on both sides and the other is black on one side and white on the other.

A card is randomly pulled from under the cloth – it's white.

Given this, what's the probability that its other side is also white?

6. False-positive

1 in 100,000 people have a certain disease. The test for this is 99.9% accurate.

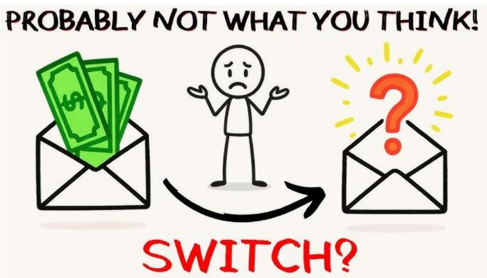
Bobbie administered the test and reports that it has comes back positive.

What are the odds that you actually have the disease?

Can you always trust expectation values though? Consider playing the following game…

7. Two Envelopes Paradox?

Envelopes, labelled A and B, contain cheques for a certain amount of money. You know for certain that one is double the value of the other.



a) Let's say you pick A, you open it up and the cheque is for £250. You're now given the option to stick or twist – what should you do?

b) Now play another round with envelopes C and D. This time you pick envelope D. The cheque says it's for an amount x, will you stick or twist now?

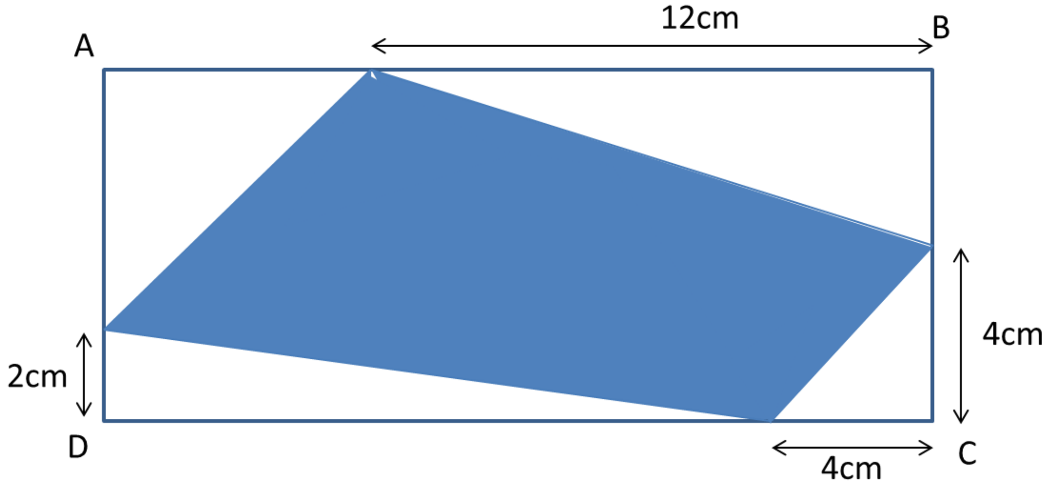
c) Final time, Envelopes E and F – take your pick. But before you even open it, aren't you just going to choose the other one anyway? Why not just pick that one at the start then?

Part II: Building a problem solving toolbelt

The relationship between the next set of problems is that they can all be solved in under 2 minutes. They may initially look hard, but are surprisingly simple, if you can find the right approach!

8. Rectangle

Rectangle ABCD below has an area of 120cm^2.



Find the area of the shaded part.

9. Ant

An ant is at one corner of a sugar cube of side length a.

How far must it travel, along the surface of the cube, to reach the far corner of the cube?

10. Squash vs water

You pour 100 ml of squash into one glass and 100 ml of water into another. You then take a 30 ml shot glass and scoop 30ml of squash into the water and give it a good mix. You then take the shot glass and transfer 30 ml of the mix back into the squash glass.

Is there more water in the squash glass or squash in the water glass?

11. Two Painters

Aled and Morgan offer to paint the outside of my house.

Aled says he'll complete the job in 3 days, whereas Morgan claims they can do the job in only 2 days.

I'm in a rush so I hire them both to work together, one going clockwise and the other anticlockwise around the house.

How long should it take to complete the job together?

12. Three Painters

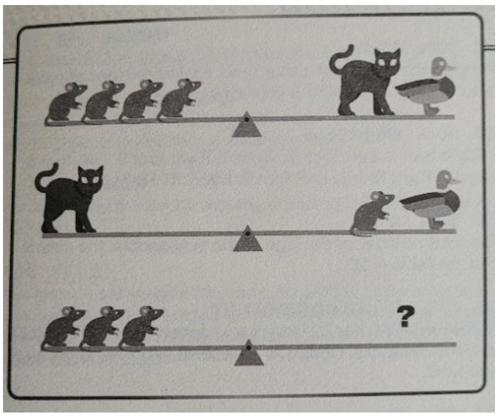
Kam and Chris spend 4 hours painting a fence together, then Femi helps out and the job is finished in 2 more hours.

Had Femi not helped it would have taken Kam and Chris 5 more hours to finish working together.

How long would it take Femi to have painted the fence on her own?

13. Rats

How many ducks would be needed
to balance 3 rats?



14. Punting

Sam punts 2 miles down the river Cam from Silver Street to Granchester Meadows in 5 hours.

After re-energising with some tea and scones, they punt at the same rate during the return journey, but this only takes 3 hours.

How fast is the current?

Hints for Webinar 1: Think Like a Physicist

1. **Die rolls:** Is each roll independent of the previous roll? We like to spot apparent patterns, but what actually is random? Can you come up with a truly random 8-digit number?

2. **π versus e**: What property unites these two rivals? What role does infinity play with probabilities? Could a monkey type out the works of Shakespeare?[11]

3. **Monty Hall:** Don't let your gut or emotions fool you, this is a purely probabilistic question. Consider whether your choice would affect whether the gameshow host could open a door containing a goat? Imagine playing a version with 100 doors and 99 goats. The host could open 98 doors to leave you a 50-50 choice at the end. Is it really 50-50 though?

4. **3-daughters:** What are the 8 possible combinations given no information, assuming the events are all independent and it's equally likely to give birth to a boy or girl? Which option(s) does the given information actually eliminate?

5. **Black and White:** Are you equally likely to have picked the black/white card as you are to have picked the white/white card?

6. **False positive:** Consider how many people will be told they have the disease.

7. **Two Envelope Paradox?** There is no point to switching – it is not advantageous. Where is the flaw in the expectation value calculation?

8. **Rectangle**: I took this question from a test for primary school children in Singapore. Try breaking the shaded area up into more familiar shapes. For every unshaded triangle, can you find an equivalent shaded triangle?

9. **Squash v Water:** What is the final volume of liquid in each glass? Although numbers are given here, they are not necessary to solve this.

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[11] Jade (Up and Atom) explores this and various other paradoxes/consequences of infinities: https://www.youtube.com/watch?v=ND9eyW5Fw0s

10. **Ant:** Can you turn this into a 2-dimensional problem?

11. **Two Painters**: From the information given, consider how much each person can paint in one day. Express this as a daily rate.

12. **Three Painters:** What is the rate that Kam and Chris work at together? How much of the fence would they have completed in 6 hours?

13. **Rats:** This is obviously solved using simultaneous equations, but could you do that in 30 seconds in your head? Can you spot a simpler method?

14. **Punting**: Consider the relative speeds for both legs of the journey – this will give you 2 simultaneous equations to solve. You could practice transferring into the frame of reference of Adrian being stationary to check you get the same answer – although in this case it doesn't simplify things.

Problem Set 1: Think Like a Physicist

Issued on 11th June 2026 solutions webinar hosted on 17th June 2026

1. **Warm up** [No calculator]

A race has 2026 entrants, all numbered from 1 to 2026 at random.

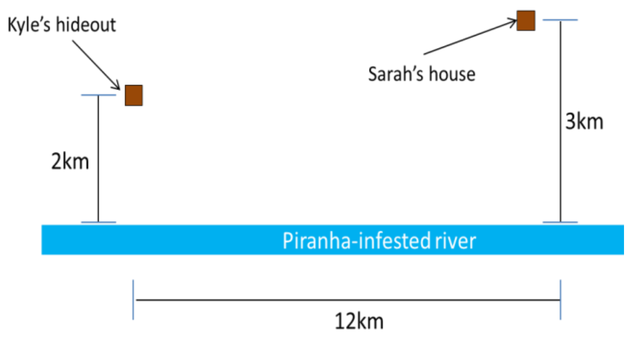
What is the probability that the first three runners to cross the finish line are numbered in ascending order?

*Note – they do **not** need to be consecutive, for example 172, 560, 1843 is ok.*

2. **Fetching Water**

Sarah Connor is living off the grid and does not have access to fresh water. Following a recent impaling, she is unable to walk. Her survival is vital for the future of humanity. Each day Kyle Rees must travel from his hideout with a bucket, which he fills with water from the piranha-infested river. Needing to conserve his strength (he's also injured), he doesn't want to walk further than is absolutely necessary.

What is the minimum distance Kyle needs to travel to get to Sarah's house via the river?



3. **Coach ride**

A person travels from Newcastle to Oxford by coach. Traffic is free-flowing and the coach's speed is only limited by whether the road is flat (63 mph), uphill (56 mph) or downhill (72 mph).

The coach ride takes 4 hours from Newcastle to Oxford, but the return journey, which follows the same roads, takes an hour longer.

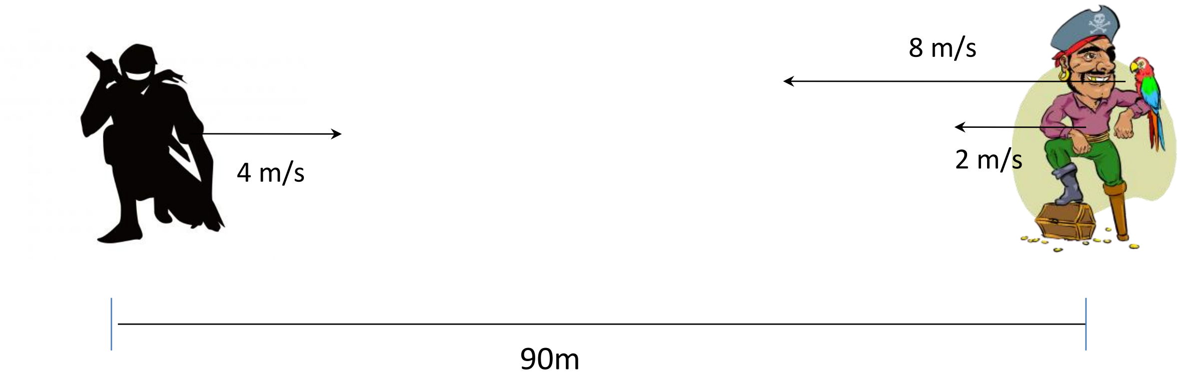
How many miles is the coach ride between Newcastle and Oxford?

4. **Pirate v Ninja** [No calculator]

It's finally time for a battle to end the long running dispute between pirates and ninjas. They face off at 90 m. The pirate limps towards the ninja at 2 ms^{-1}, while the ninja glides towards the pirate at twice the speed.

It is only a matter of time before they collide and crush the loyal parrot which repeatedly flies back and forth at a constant speed of 8ms^{-1}, elastically bouncing off the two.

What is the total distance the poor parrot travels before being crushed?



5. **Trams in Geneva**

On a school trip to visit CERN, I walk down a long street at 1 m/s for an hour. During this time, I count the number of trams that pass me by.

Knowing that they follow a regular timetable in both directions I am initially surprised to note that only 15 trams overtake me, whereas 20 passed me head on.

What is the average speed of the trams?

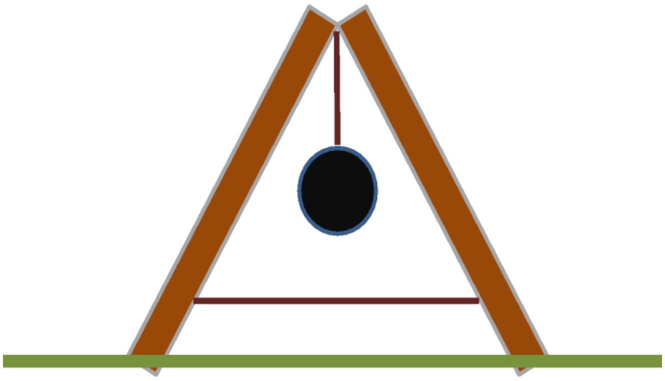
6. **Marble in a Fishbowl** [No calculator]

A 'fishbowl' of height 4r/3 is formed by removing the top third of a sphere (radius r). The fishbowl is fixed in sand so that its rim is parallel with the ground. A small marble of mass m rests at the bottom of the fishbowl.

Find the maximum initial velocity that could be given to the marble for it to land back in the fishbowl.

Hint: Assume all surfaces are frictionless and ignore air resistance.

7. **Trusses** [No calculator – use g ~ 10 m/s^2]



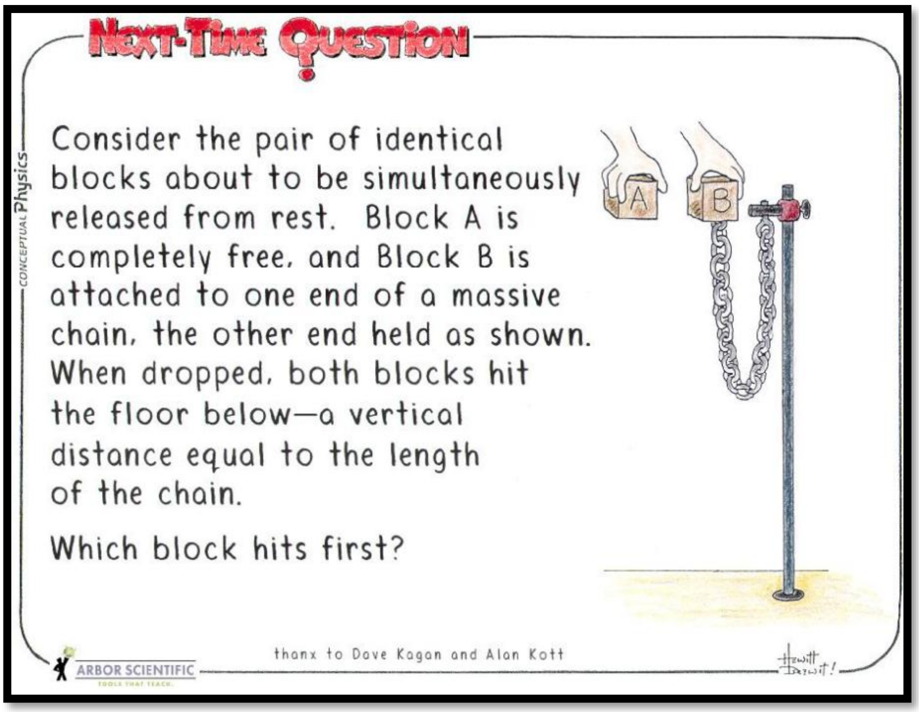
A ball of weight 500 N is suspended from the apex of the structure shown on the left. The structure is made of two trusses, each of length 3.0 m and mass 40 kg.

A 3.0 m horizontal rope connects the trusses, tied a sixth of the way up the trusses.

If the structure were placed on an ice-rink, calculate the resulting tension in the rope.

8. **Race against gravity**

Answer this conceptual question from Paul Hewitt. Be sure to justify your answer[12].



[12] Derek from Veritasium actually does this experiment: https://www.youtube.com/watch?v=1erU-Cwcl2c

Hints for Problem Set 1: Think like a physicist

1. **Warm Up:** I ask this question every year, but I always add one more runner, the answer is always the same.
   It may be useful to not focus on the numbers – why not label the winners A, B, C instead?

2. **Fetching Water:** What is the quickest way between any two points?
   Can you ask an equivalent question following the path of a ray of light?
   One approach would be to find the minimum distance using calculus, but there is a much neater solution.

3. **Coach Ride:** Split the journey into 3 sections of length x, y and z. What happens to the downhill sections on the return journey? What are you trying to find in terms of x, y and z? Do you care what each of them are? The numbers have been chosen carefully – can you tidy up awkward fractions?

4. **Pirate v Ninja:** One approach would be to find the positions where the parrot changes direction. Given the speed, but asked to find distance – what else would it be useful to know?

5. **Trams in Geneva:** A diagram is very useful – remember to include how far you walk in between each tram passing you. Try switching into your frame-of-reference, i.e. when you are stationary – what's the relative velocities of the trams now? This might be similar to a Doppler shift.

6. **Marble in a Fishbowl**: Identify the physics principles involved. Draw a large, clear diagram with all key information labelled. Plan your route through the problem. THEN solve.

7. **Trusses**: Think about if you can simplify the problem, where might be the best place to take moments about? Make sure you have a clear diagram with all forces labelled.

8. **Race against gravity:** What are the forces acting on A and B immediately after they are released? How do these change over time? Could this be related to the Chain Fountain (aka Mould[13] effect)?

[13] https://www.youtube.com/watch?v=qTLR7FwXUU4

Webinar 2: Tackling Physics Problems

24th June 2026

1. Bouncy Ball

A ball of mass 0.125 kg bounces on a hard surface. Every time it hits the floor, it loses a quarter of its kinetic energy. The ball is released from a height of 1.00 m.

After how many bounces will the ball bounce no higher than 0.25 m?

2. The Snowman

You want to make a snowman out of modelling clay. The snowman consists of two spheres, where one sphere has a radius r, and the other has a radius $2r$. The modelling clay comes in the form of a cylinder with radius $r/2$.

What length of modelling clay is required to make the snowman?

3. Mass on springs

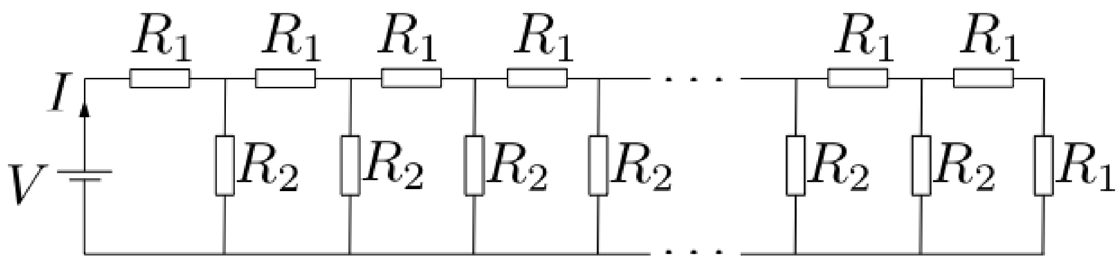
A mass m is hung from a spring with a spring constant of k. When set into motion, the mass oscillates with a period $T = 2\pi\sqrt{\frac{m}{k}}$.

Using another identical spring, what would be the period of oscillation of the mass if it were…

a. taken to a planet with a gravitational field strength of $2g$.
b. hung from the two springs connected end-to-end (in series)?
c. hung from the two springs connected side-by-side (in parallel)?

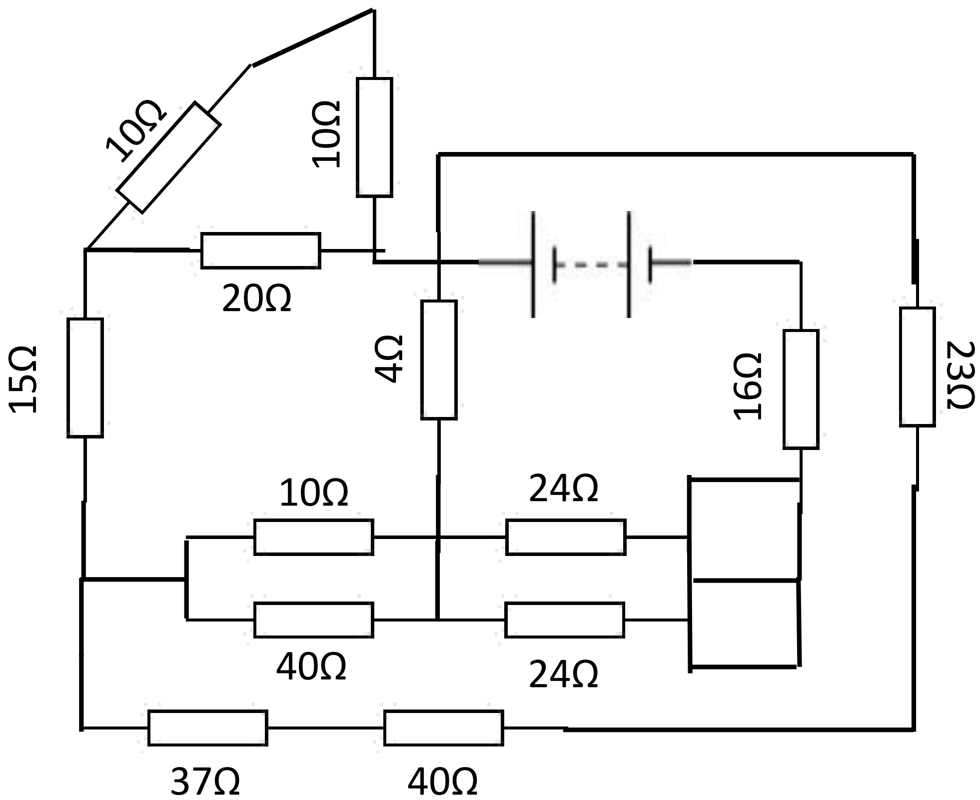
4. Infinite resistors – Part I

If In the diagram below[14], $R_1 = 10\Omega, R_2 = 20\Omega$ and $V = 10V$, find the current, I.



5. **Tangled resistor circuit** [No calculator]

If this tangled network of 13 resistors were to be replaced with a single resistor that would draw the same current from the battery, what value resistor should be chosen?

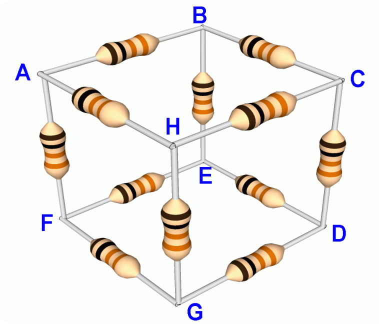


6. **Resistor networks - Part I**

[14] https://i-want-to-study-engineering.org/q/infinite_loops_circuit_1

A cube of resistors, ABCDEFGH, is made with 12 identical resistors of resistance $R = 12\Omega$.
An ohmmeter is connected to vertices A and D.

Determine the reading on the ohmmeter.



7. Motion-time graphs - Part I

A ball is thrown up in the air, loosing contact with the hand at time $t = 0$ and then caught at the same height at time $t = t_1$. Draw the velocity-time sketch for the motion of the ball for $0 \leq t \leq t_1$.

Hint: Ignore air resistance

8. Maximum range - Part I

Show that the maximum range of a cannon on flat ground is achieved by launching at an angle above the horizontal of $\theta = 45^{o}$.

9. Plutonian Caterpillars

The dwarf planet Pluto (radius 1180 km) is populated by three species of purple caterpillar. Studies have established the following facts:

- A line of 5 mauve caterpillars is as long as a line of 7 violet caterpillars.
- A line of 3 lavender caterpillars and 1 mauve caterpillar is as long as a line of 8 violet caterpillars.
- A line of 5 lavender caterpillars, 5 mauve caterpillars and 2 violet caterpillars is 1 m long in total.
- A lavender caterpillar takes 10 s to crawl the length of a violet caterpillar.
- Violet and mauve caterpillars both crawl twice as fast as lavender caterpillars.

How long would it take a mauve caterpillar to crawl around the equator of Pluto?

Building The Great Pyramid of Giza – Part I

There are several theories (including aliens) to explain how the ancient Egyptians were able to build these megastructures. The mainstream theory believes that skilled workers dragged the blocks up ramps. Let's explore whether this is physically feasible…

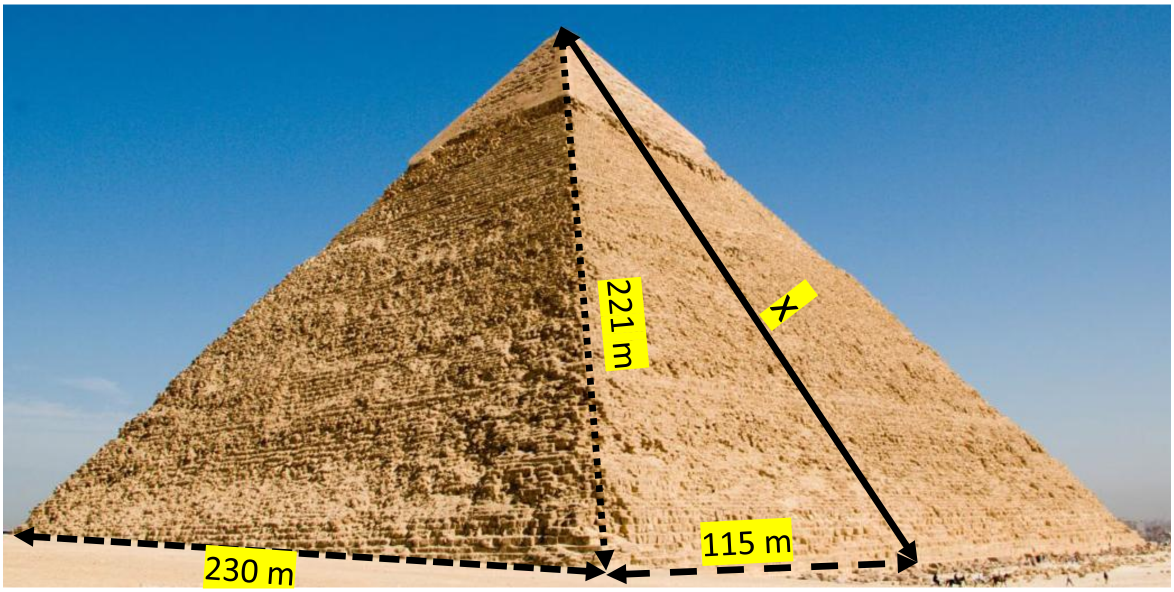
10. Rate of Construction

The great pyramid at Giza was mostly made from an estimated 2.3 million blocks of limestone, each one with a mass of approximately 2.5 tonne. Egyptologists have estimated the construction[15] only took 18 years.

Estimate the rate, in blocks per hour, at which the pyramid was constructed. State any assumptions you make.

11. Dimensions

When the pyramid was originally built it had a square base of side length 230 m and a corner-apex distance of 221 m as shown.



Calculate the vertical height of the pyramid and the length of the slope mid-way along a side, marked x in the photograph.

12. Pulling Force

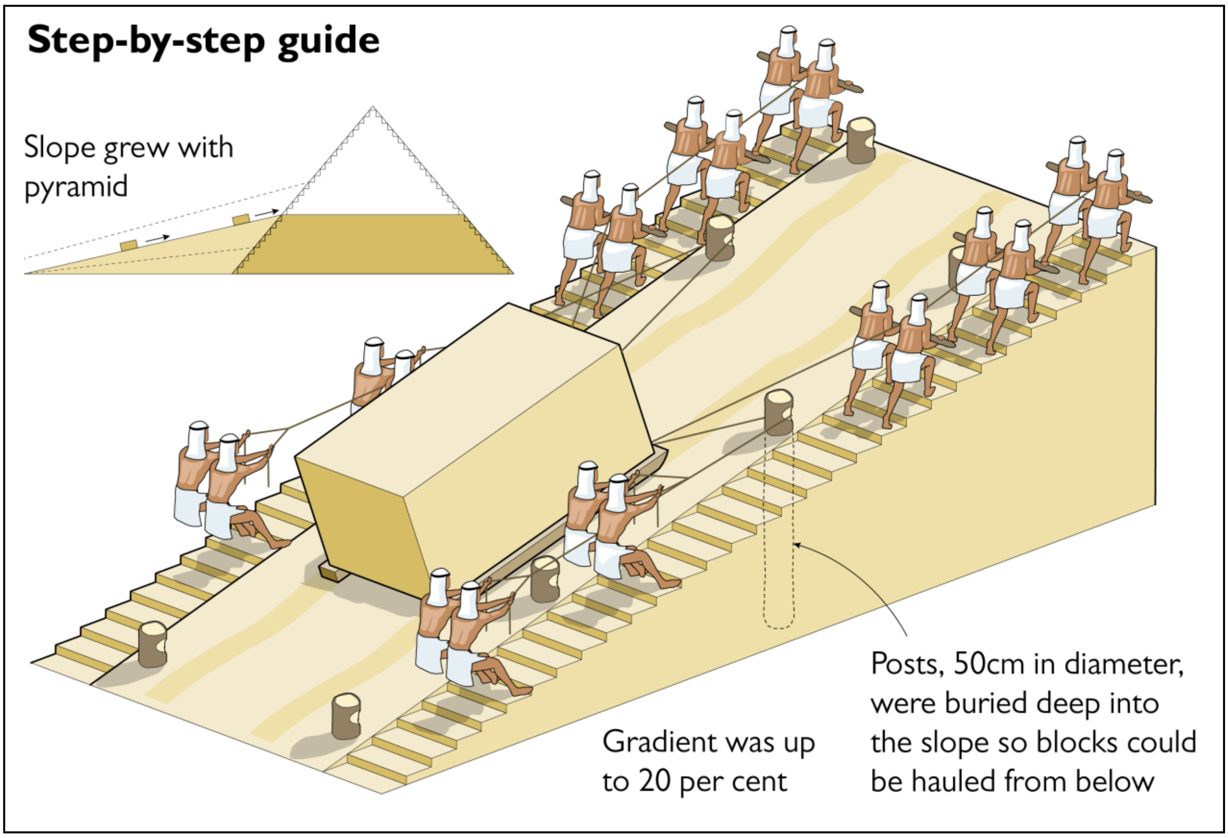
[15] Although with the planning, it was probably a 27 year project: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://fundacionieae.es/wp-content/uploads/2024/08/Brichieri-Colombi_PJAEE_12_1_2015.pdf

The coefficient of static friction between sand & wood is around 0.7. Assume the team of twenty workers is each able to apply a force equal to their body weight.

Show that the incline of the side of the pyramid is close to the hardest angle for dragging the limestone blocks up it and calculate the mass of the workers that would be required. Compare this to the estimated mass of 46 kg.

13. Simple Ramp

A discovery made in 2018 suggests the ancient Egyptians were using pulleys to increase the force they could apply.



Using the information in the picture above, estimate the volume of the final ramp structure and compare this to the volume of the great pyramid.

Hints for Webinar 2: Tackling Physics Problems

1. **Bouncy ball:** Remember that gravitational potential energy depends linearly on height above the ground. After each bounce, 75% of the energy remains, so how many times do you need to take 75% of 75% of 75% …etc. to have only 25% remaining?

2. **The Snowman:** If the larger sphere has twice the radius, it has eight () times the volume. Remember that the formulae for the volume of a sphere is $V_S = \frac{4}{3}\pi r^3$ and of a cylinder is $V_C = \pi r^2 h$.

3. **Mass on a spring:** Ask yourself what changes in each case?
   a) In this case, each spring experiences the same force of the weight of the mass. What effect does this have on k and therefore T?
   b) In this case, each spring experiences half the force of the weight of the mass. What effect does this have on k and therefore T?
   c) Once the ball has reached its highest point, it is essentially just falling the rest of the time. Remember that you can calculate both the negative and positive displacement using suvat equations.

4. **Infinite resistors:** Problems like this are often about recognising a pattern. Start with a smaller chain and see what happens as you keep adding more and more segments.

5. **Tangled resistor circuit:** Redraw the circuit in a more useful/recognizable format, and simplify pairs of resistors as you go. DO NOT try to do it all in one go.

6. **Resistor networks:** What are the symmetries? Re-draw the network in a more familiar format. No net current will flow between points with the same potential.

7. **Motion-time graphs:** Your intuition will likely mislead you. Start with a free-body force diagram, link this to acceleration, and then link that to velocity and finally displacement. Split the journey up into regions when the behaviour changes.

8. **Maximum range Part I:** You'll find it helpful to know your trig identities, and for this particular problem: $2\sin x \cos x \equiv \sin 2x$

In general, follow this step-by-step guide and you'll solve most projectiles problems:

- Draw a clear diagram showing all the information given and what you're asked to find.
- Split any velocity vectors (usually given the initial velocity) into horizontal and vertical components.
- Set up sign convention: which horizontal (x) and vertical (y) directions are positive?
- Write out 2 sets of SUVAT, being careful about minus signs.
- The time of flight will be the same in both directions, so you can often find this by resolving vertically and use this to find the horizontal range.

9. **Plutonian Caterpillars:** Take the 5 bullet points and turn them into mathematical expressions – you'll want to simplify this as much as possible so pick sensible symbols for the speeds and lengths of the 3 types of caterpillar.

10. **Rate of Construction:** You'll need to make realistic assumptions – how many days a week/year will people be working – remember they weren't slaves! How many hours on average could they work doing hard manual labour?

11. **Dimensions:** 3D drawing/visualisation is tricky, it's generally a much better idea to split it into two 2D pictures. Then all you'll really need is Pythagoras' theorem.

12. **Pulling Force:** A nice free-body diagram of a mass on a rough slope is the starting point. To determine a maximum (or minimum) you'll want to differentiate your expression for force with respect to the angle.

13. **Simple Ramp:** Did you spot that the posts were 50 cm in diameter and the slope was 20% - what does that mean?
Don't forget that you can use the existing pyramid as part of the ramp to reduce the extra volume needed.

Problem Set 2: Tackling Physics Problems

Issued on 25th June 2026, solutions webinar hosted on 1st July 2026

1. Drag dimensions

The drag force F on a sphere is related to the radius of the sphere, r, the velocity of the sphere, v, and the coefficient of viscosity of the fluid the drop is falling through, η, by the formula

$$F = k\, r^x\, \eta^y\, v^z$$

where k is a dimensionless constant, and x, y, and z are integers.

By considering the units of the equation, work out the values of x, y, and z.

Note: The coefficient of viscosity has units of [kg $m^{-1}s^{-1}$].

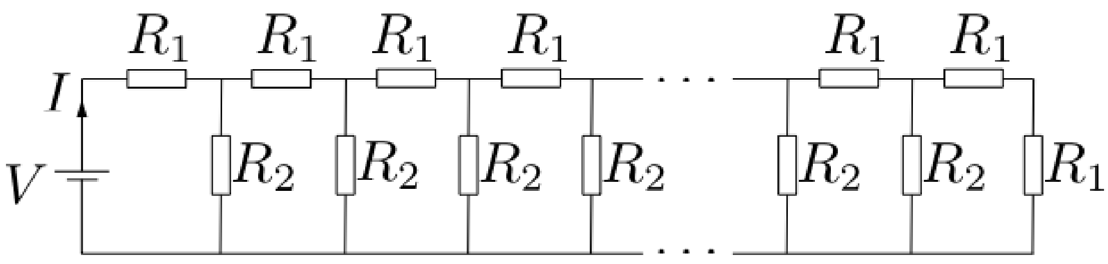
2. Radioactive decay

A radioactive sample contains two different isotopes, A and B. A has a half-life of 3 days, and B has a half-life of 6 days. Initially in the sample there are twice as many atoms of A as of B.

At what time will the ratio of the number of atoms of A to B be reversed?

3. Infinite resistors – Part II

In the circuit diagram below, let $R_1 = R_2 = 10\Omega$ and $V = 10V$. [16]



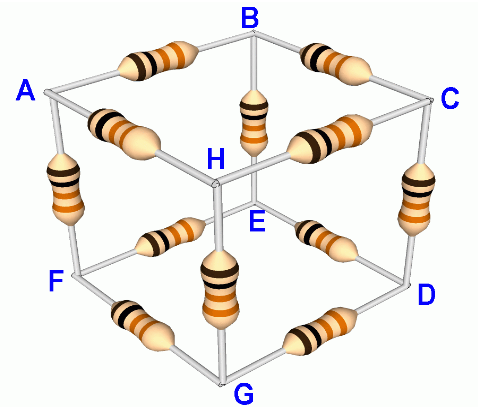
Calculate the value of I.

4. Resistor networks Part II

[16] https://i-want-to-study-engineering.org/q/infinite_loops_circuit_2

A cube of resistors, ABCDEFGH, is made with 12 identical resistors of resistance R.

Determine all the possible values of resistance (in terms of R) that could be produced by connecting an ohmmeter to any pair of vertices (e.g. A-B, A-C, A-D etc....)



5. Maximum range - Parts II

Show that, if the cannon is at the top of a hill, with an incline of ϕ, then the range equation can now be written as:

$$R = \frac{u^2}{g}[sin\ 2\theta\ + tan\ \phi\{1 + cos\ 2\theta\ \}].$$

6. Maximum range - Part III

Determine the relationship between θ and ϕ that maximizes the range.

7. Motion-time graphs - Part II

A football is dropped from the leaning tower of Pisa, accelerating to close to its terminal velocity before hitting the ground.

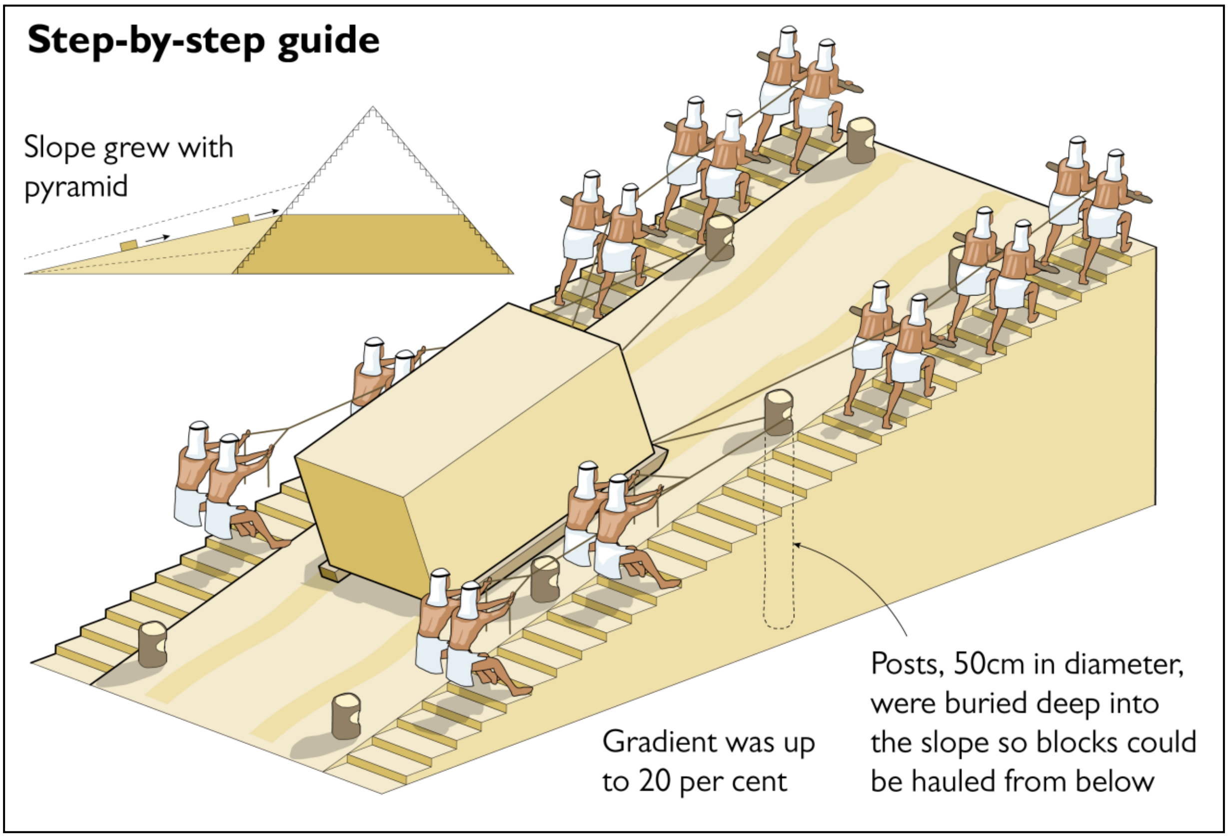
It rebounds inelastically, reaching a third of its original height – for this part of its motion we can neglect the effect of air resistance.

Sketch the motion graphs (displacement-, velocity- and acceleration-time) from the moment of release until it hits the ground for a second time.

Building The Great Pyramid of Giza – Part II

Estimating the width of the slope as 7 m by using the 50 cm diameter posts for scale, the volume of the ramp would have been around $1.81 \times 10^5\ \mathrm{m}^3$ or ~6.8% the volume of the pyramid. Scholars suspect the ramp would have been closer to double this width however.

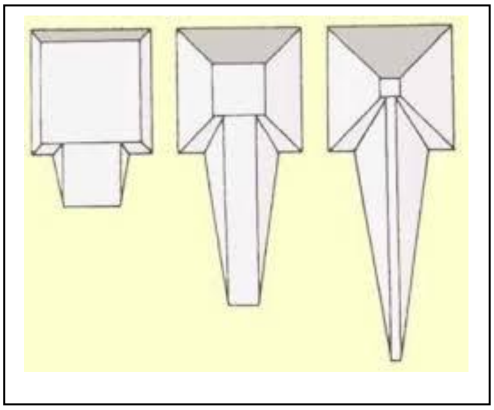
If the ramp were made of sand (or other granular materials), the sides would not have been vertical. The angle of repose (angle of slope from the horizontal) is usually $30 - 45°$ for such materials.



8. Realistic Sand Ramp

To estimate the size of a sand ramp with sloped sides, the maths will quickly become quite ugly, so let's do what physicists do – start with a simple model, then add layers of complexity if we fancy the challenge.

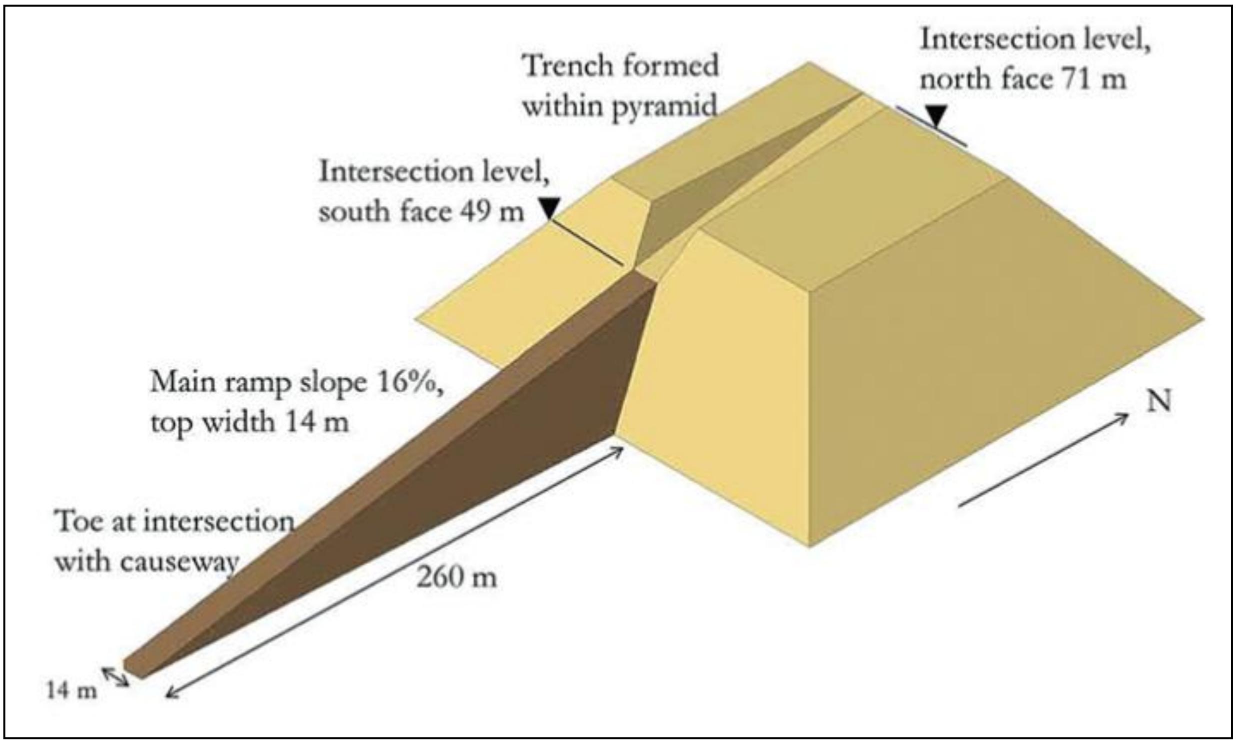
a) Let's draw a ramp 14 m wide, with an $18°$ slope that meets the pyramid when it's also 14 m wide. Assume the sides of the ramp made a $45°$ angle with the horizontal as almost shown in the depiction on the right.



Now ignore the pyramid and just calculate the volume of such a ramp.

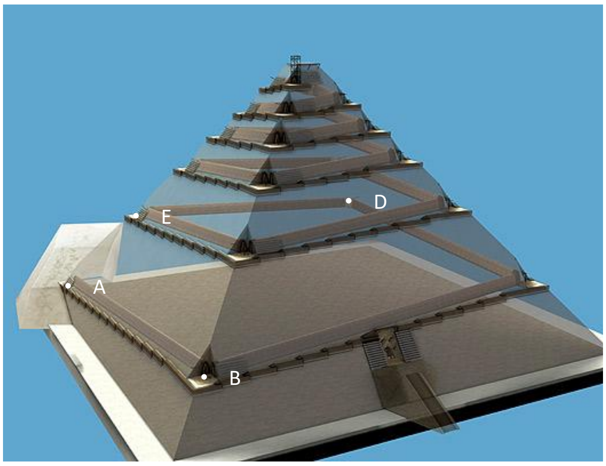
b) If we put the pyramid back in place, it would intersect a portion of this ramp, so if we subtract that intersection, it would give us a better estimate for the volume of the ramp.

c) We could save even more volume if instead of meeting the pyramid on its near side, it actually stopped when it got to where the far side was 14 m. The picture below shows this idea, but meeting it lower down without the side slopes.



A giant ramp of this type seems quite unlikely and there is little evidence of it[17] actually existing. However, there has been evidence that supports the idea of ramps spiralling around the pyramid with the pyramid itself providing the majority of the necessary support structure.

9. Spiral Ramp



The figure depicts such a structure with an incline of only 6.4°, which will vastly reduce the force the workers needed to apply. There is also evidence of the workers lubricating the ramps to further reduce the coefficient of friction to around 0.25.

However, the largest granite blocks in the Kings Chamber weighed 50-80 tonnes!

Assume that the ramp at point A starts at a corner of the pyramid, at its base. Calculate the distance between the following points as represented in the figure above

a. A and B
b. A and E – following the spiral path.

Hint: draw a large and well-annotated 2D diagram to start with. Once you've found the first distance, look for symmetries to reduce the number of steps.

10. Total length

Find, in **two** different ways, the total distance from A to the apex up the inclined ramp.

Hint: assume the spiraling never stops.

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[17] 6,000 years is probably long enough for the wind to blow the sand away though.

Hints for Problem Set 2: Tackling Physics problems

1. **Drag Dimensions:** This problem boils down to solving the equation:
   $$\text{kg ms}^{-2} = (\text{m})^x (\text{kg m}^{-1}\text{s}^{-1})^y (\text{ms}^{-1})^z$$
   Remember that $(ab)^x = a^x b^x$ and note that there is only one kilogram term on either side of the equals sign.

2. **Radioactive Decay:** There are two factors of two in the question: there are twice as many atoms of A than B, so and the half-life of B is twice that of A.
   Use $N = N_0 e^{-\lambda t}$ and remember that you are looking for the situation to be reversed, i.e. $N_A = \frac{N_B}{2}$.
   Given the numbers are particularly nice, maybe trial and error would be a quick, but unsatisfactory, approach.

3. **Infinite resistors Part II: I**t's the same approach as before but without nice numbers given you'll have to find an algebraic expression to link the resistance of the chain to the previous one.
   Because the chain is infinite you can say that $R_{n+1} = R_n$

4. **Resistor networks Part II:** You've already calculated A-D, so that's only 6 left you need to do, or do you? Won't A-B, A-H and A-F be the same by symmetry?

5. **Maximum range Part II:** A clear diagram is always important, more so for tricky problems like this. A stepping stone along the way will be this equation:
   $$\frac{1}{2}gt^2 - u\sin\theta\, t - R\tan\phi = 0.$$
   You'll find it helpful here to know that: $\cos 2x \equiv 1 - x$

6. **Maximum range Part III:** Sorry – there's no clever shortcut here, you're going to have to differentiate!
   You'll find it helpful here to know that: $\cot\phi = \tan\left(\frac{\pi}{2} - \phi\right)$
   Your final expression should be reassuringly simple, and it must resemble what you should have found in part 1 when $\phi = 0$.

7. **Motion graphs Part II:** Split the motion into sections.... Free fall / drag starts to grow / terminal velocity / bouncing / free fall again. Start with acceleration-time and work through to velocity then displacement.

8. **Realistic Sand Ramp:**

   a) I found it useful to break the cross-section into three parts, one of which you've already done the work for. Using symmetry, you only really need to work out the volume of one side of the sloped ramp. I then set up an integral over the length of the ramp, but is there an easier way?

   b) Since the ramp is wider than the pyramid, we can simply subtract half the area of the pyramid. This is a first approximation, now since a large volume of the ramp is being supported by the solid structure of the pyramid, you can imagine that the side ramps could be made steeper, thus decreasing their volume further.

   c) Break it down into as many manageable chunks as you can.

9. **Spiral Ramp:** I first turned this 3D problem into a 2D problem by rotating the face about its base edge until the apex was vertical. However, will this change the value of theta? Once you've done that, find an expression for the length of the ramp using Pythagoras' theorem, and then use trigonometry and lots of right-angled triangles to find expressions for these side lengths.

10. **Total length:** When I first solved this, I was very pleased to recognise that there was a convergent infinite geometric series here, due to the symmetric nature of the problem. On reflection, I now realise that there is a much quicker way when I unwrap the problem properly.